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Larval distribution patterns and habitat characteristics of two apaturinid butterflies, *Hestina japonica* C. & R. Felder and *Sasakia charonda* (Hewitson), in Mooka City, Tochigi Prefecture, central Japan

Takato KOBAYASHI[1)]* and Masahiko KITAHARA[2)]

[1)] Laboratory of Applied Entomology, Faculty of Agriculture, Utsunomiya University, Mine 350, Utsunomiya, Tochigi, 321-8505 Japan
[2)] Laboratory of Animal Ecology, Yamanashi Institute of Environmental Sciences, 5597-1 Kenmarubi, Kamiyoshida, Fujiyoshida, Yamanashi, 403-0005 Japan

Abstract Two butterfly species, *Sasakia charonda* and *Hestina japonica*, have similar life cycles, which both use the same woody species as host plant and overwinter at the base of host trees during larval stages. We investigated the relationship between the density of overwintering larvae of these two butterfly species and habitat characteristics at two sites, *i. e.*, a suburban site, where secondary deciduous broadleaf forest is distributed widely and continuously, and an urban area, which had a smaller, patchier distribution of forest than the former site. Density of *S. charonda* larvae was significantly higher in the suburban site than in the urban area, while the difference in the densities of *H. japonica* larvae between the two sites was not significant. The result of a two way ANOVA, in which study site and butterfly species were set up as two independent variables, suggested that *S. charonda* might be sensitive to decrease in secondary deciduous broadleaf forest as a result of urbanization, whereas *H. japonica* is superior to *S. charonda* in adaptability to reductions in the forest and might have a different life history strategy from *S. charonda*. There was a significant positive correlation between the density of *S. charonda* larvae and the total area of all forest types or the total area of the secondary deciduous broadleaf forests, but no significant correlations were detected for *H. japonica* between them. The fact that the density of overwintering larvae of *S. charonda* was affected by reductions in secondary deciduous broadleaf forest, may be closely connected to (1) that the density of eggs laid by female adults decreased when the area of nearby secondary deciduous broadleaf forest decreased and/or (2) that the mortality rates of young- and intermediate- instar larvae increased when the area of forest decreased. On the other hand, the fact that a significant correlation was not found between the density of overwintering *H. japonica* larvae and the area of secondary deciduous broadleaf forest around the host trees may be closely related to (1) that the female adults of *H. japonica* lay eggs on host trees quite independently of the area of the secondary deciduous broadleaf forest surrounding the host trees, and/or (2) that the mortality rates and factors of this species are different from those of *S. charonda* larvae, and are not affected by the area of the forest surrounding host trees. The result of this study provided helpful clues for clarifying the reason why *S. charonda* and *H. japonica* coexist to some extent geographically, but their local distribution patterns differ from each other in Japan.

Key words Distribution patterns, habitat characteristics, *Hestina japonica*, *Sasakia charonda*, secondary deciduous broadleaf forests.

Introduction

Many studies have reported that habitats of some insect species that rely on similar host plants and have similar life cycles overlap to some extent geographically (*e. g.* Ohsaki, 1979; Inoue, 1990; Morimoto *et al.*, 1991). To clarify the coexistence mechanism of shap-

*Present address: Laboratory of Animal Ecology, Yamanashi Institute of Environmental Sciences, 5597-1 Kenmarubi, Kamiyoshida, Fujiyoshida, Yamanashi, 403-0005 Japan;
e-mail: t.koba@yies.pref.yamanashi.jp.

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ing guild structure is one of the most important aims of community ecology. Also, an examination of differences in resource utilization patterns among the species is the first step in studying the coexistence mechanism of species (*e. g.* Price, 1984).

Sasakia charonda and *Hestina japonica* (Lepidoptera, Nymphalidae, Apaturinae) have similar life cycles: both use the same host trees, *Celtis sinensis* and/or *Celtis jezoensis*, and overwinter at the base of host trees during larval stages. In Japan, these two species coexist to some extent geographically, but they have different habitat utilization patterns within a locality (Fukuda *et al.*, 1983). That is, both species inhabit suburban areas, where secondary deciduous broadleaf forests are widely and continuously distributed (Fukuda *et al.*, 1983, Kobayashi, 2000*b*). However, *H. japonica* inhabits urban areas, where the forested areas have been reduced as a result of land development, but *S. charonda* does not (Fukuda *et al.*, 1983, Kobayashi, 2000*b*). At present, *S. charonda* is a near-threatened species in Japan (Ministry of the Environment, 2000), probably due to its more restricted habitat requirements than those of *H. japonica*. However, little is known about why they coexist to some extent geographically, but have different local distribution patterns in Japan.

To obtain the fundamental data for conservation of *S. charonda*, in the suburban and urban areas at Mooka City, Tochigi Prefecture, central Japan, Kobayashi *et al.* (2004) investigated the relationship between the density of overwintering *S. charonda* larvae per host tree and habitat characteristics, *e. g.* areas of secondary forests within a radius of 100 m of the host tree and types of adjacent land uses. They found that, when the area of nearby broadleaf forests decreased and the area of paddies, crop fields, or residential land increased, the density of the larvae decreased. In the study, they also recorded the larval density of *H. japonica* per host tree, but they have not yet analyzed their data. To compare the relationship between the density of overwintering larvae per host tree and habitat characteristics between the two species may provide clues to clarify why these species coexist to some extent geographically, but have different local distribution patterns in Japan.

In the present study, we investigated the relationship between the larval density of *H. japonica* or *S. charonda* and habitat characteristics in suburban and urban areas, and we discussed the differences in the local distribution patterns between the two species on the basis of these results.

Study sites and methods

Study sites

We established a circular study area with a radius of 1,500 m in Shimokomoriya (SK), northwest of the center of Mooka city, Tochigi Prefecture, central Japan, and in Isesaki (IS), west of the city center (Fig. 1.). The SK site was located in a suburban area, where forests are widely and continuously distributed. At the IS site, because urbanization has advanced rapidly in recent years, the forest area was smaller with a patchier distribution than that at SK. The forested areas at the SK and IS sites were 25% and 12%, respectively (Kobayashi *et al.*, 2004). The forests at both sites mainly consisted of secondary deciduous broadleaf, coniferous and bamboo forests. The broadleaf forests contained patches of three types of forests: secondary mixed forest dominated by *Castanea crenata*, *Quercus serrata*, *Swida controversa* and *Styrax japonica*, and plantations of *Quercus acutissima* and *Q. serrata* (Kobayashi *et al.*, 2004). The coniferous forests comprised plantations of *Cryptomeria japonica* or *Chamaecyparis obtusa*. The secondary mixed forests were more widely distributed than were the plantations of *Quercus acutissima*, *Q. serrata*, bamboo and *Cryptomeria japonica* or *Chamaecyparis obtusa* (Kobayashi *et al.*, 2004). At the two study

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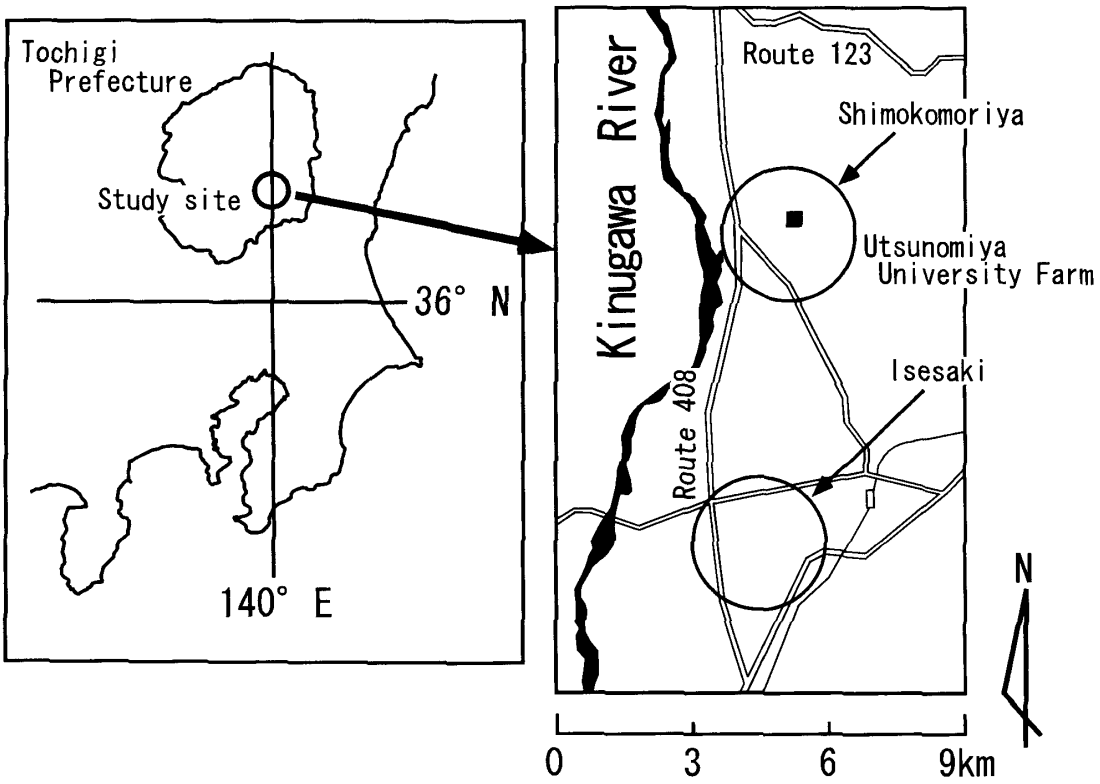

Fig. 1. Map of the two study sites for *Hestina japonica* and *Sasakia charonda*, in Mooka City, Tochigi Prefecture, central Japan.

sites, only *C. sinensis* hosts larval *S. charonda* and *H. japonica* (Kobayashi *et al.*, 2004). At both sites, *C. sinensis* regenerates and grows in abandoned fields, around the farmhouses and at forest edges. The number of host trees was largest in the secondary mixed forest dominated by *Castanea crenata*, *Quercus serrata*, *Swida controversa* and *Styrax japonica* (Kobayashi *et al.*, 2004).

Density of overwintering larvae per host tree and habitat conditions around host trees

(1) Density of larvae per host tree

We found 81 and 201 host trees (tree height: >2 m) in the SK and IS site, respectively (Kobayashi *et al.*, 2004). We researched only trees, whose height was >2 m, because the number of trees of all sizes was too large to be practicable. During the period from the last ten days of November to the last ten days of December 1996, we randomly sampled 42 and 54 host trees, whose height was >2 m in the SK and IS site, respectively. All these trees were located at the edge of the secondary mixed forest dominated by *C. crenata*, *Q. serrata*, *S. controversa* and *S. japonica*. We then collected litter from within 50 cm of the bases of those trees as carefully as possible and counted the number of *S. charonda* and *H. japonica* larvae per host tree in our laboratory.

The difference in the larval density of each butterfly species per host tree between the two sites was tested by Mann-Whitney *U*-test. We used two way ANOVA to test whether the difference in the densities of overwintering larvae between the two study sites significantly differed between *S. charonda* and *H. japonica*. Butterfly species and study sites were set up as the independent variables in the two way ANOVA.

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(2) Relationship between larval density per host tree and habitat conditions around host trees

The sap of *Q. acutissima* is a major food resource for adult *S. charonda* in and near Mooka City (Kobayasi and Inaizumi, 2003; Kobayashi and Kitahara, in press). Density of overwintering larvae of *S. charonda* per host tree varied depending on the size of the host tree (Kobayashi *et al.*, 2004). Mortality rates or factors of inoculated *S. charonda* larvae (Kobayashi and Inaizumi, 2002) and the density of eggs laid by the female adults per host tree (Kobayashi and Kitahara, in press) varied depending on the percentage of the area of a broadleaf forest within a radius of 100 m of the host tree. The density of eggs laid by the female adults per host tree may be also affected by whether there are obstacles such as buildings surrounding the host tree, which were likely to disturb the adult flying. Therefore, we focused on the following six factors as the habitat characteristics around the focal host trees where we counted the number of larvae of the two butterfly species: (1) distances from a focal tree to the nearest stand of *Q. acutissima*, (2) the number of host trees surrounding the focal host tree (this number contained the focal host tree), (3) and (4) the total area of all forest types, and the total area of secondary deciduous broadleaf forest surrounding the focal host tree, and (5) type of land use adjacent to the forest edge containing the focal host trees, (6) size of the focal host trees. We tested the relationship between the larval density per host tree and these six habitat characteristics.

We measured the diameter at the breast height (DBH) of the focal trees at the two study sites. We used DBH as an index of the size of a focal tree. We identified areas of wood deciphering aerial photographs at the two study sites (published by Geographical Survey Institute in 1993, scale: 1/25,000).

We walked around all areas of the wood, and found the following seven types of forest: (1) plantations of *Quercus acutissima*, (2) *Quercus serrata*, (3) coniferous tree (*Cryptomeria japonica* or *Chamaecyparis obtusa*) or (4) bamboo (*Phyllostachys heterocycla* or *Phyllostachys bambusoides*), (5) secondary mixed forest dominated by *Castanea crenata*, *Quercus serrata*, *Swida controversa* and *Styrax japonica*, (6) windbreak forests and (7) forest parks. The structures of these forests were reported by Kobayashi *et al.* (2004). Then, we walked again around all areas of the wood with a blank map (1/10,000), on which land use was recorded, and areas of each type of forest were painted with different color on the map. The locations of all host trees (SK site : 81, IS site: 201), whose height was >2 m, were also indicated on these maps.

Using the maps, on which areas of each type of forest were drawn and location of host trees were dotted, we measured the straight distances from each focal tree to the nearest stand of *Q. acutissima*. We drew a circle with a 100 m radius around each focal tree, counted the number of host trees (containing the focal tree) within the circle, and measured the total area of all forest types and the total area of secondary deciduous broadleaf forests (plantations of *Q. acutissima* or *Q. serrata* and secondary mixed forest dominated by *C. crenata*, *Q. serrata*, *S. controversa* and *S. japonica*) within the circle using an area scale with dot grids S-II (Japan Forest Technical Association, 1963).

As mentioned above, all focal trees were located at the edge of secondary mixed forest dominated by *C. crenata*, *Q. serrata*, *S. controversa* and *S. japonica*. Within the circle with a 100 m radius around each focal tree, we identified the type of land use of the area adjacent to the forest edge where a focal tree was present. The land uses identified were the following ten types: (1) ferroconcrete two- or more- story buildings, (2) gravel parking area, (3) asphalt roads, (4) non-paved narrow footpaths where only small farming vehicles can pass, (5) paddies, (6) crop fields, (7) waste fields, (8) grasslands, (9) ponds, and (10)

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Table 1. Mean value of each habitat component on focal host trees and number of the trees classified into type 0 in each site (Kobayashi *et al.*, 2004).

	Study site		
	Shimokomoriya	Isesaki	*t*, *P*
Mean value of each habitat component on focal host trees			
DBH of trees (cm)	16.9±8.2	19.6±10.6	t=–1.34, P=0.18[1]
Total area of all forest types around a tree (m²)	13790±4847	11822±6655	t=2.81, P<0.01[1]
Total area of secondary deciduous broadleaf forest around a tree (m²)	10791±5615	8667±5884	t=2.70, P<0.01[1]
Distance from trees to the nearest *Q. acutissima* stand (m)	154.7±123.4	158.1±126.2	t=–1.60, P=0.87[2]
Number of *C. sinensis* trees around the focal host trees[3]	3.3±1.6	6.7±5.3	t=–3.96, P<0.01[1]
	Shimokomoriya	Isesaki	χ^2, *P*
Number of the trees classified into type 0[4] (% to number of all focal trees)	6 (14%)	24 (44%)	χ^2 =8.65, P<0.01[3]

[1] Real value in each tree was log-transformed, and then, the difference in the transformed values between the two sites was tested by *t*-test.
[2] Real value in each tree plus 1 was log-transformed, and then, the difference in the transformed values between the two sites was tested by *t*-test.
[3] This number contained the focal host tree.
[4] The difference in proportion of number of the trees classified into type 0 to total number of focal trees between the two sites was tested by Chi-squared test.

farmer's one-storied houses. Among them, ferroconcrete two- or more- story buildings, gravel parking area and asphalt roads were defined as the type of land use which were likely to prevent female adults from flying to the focal host trees (type 0), because ferroconcrete two- or more- story buildings seemed to reduce flying spaces for female adults and gravel parking area and asphalt roads seemed to promote heavy traffic. Non-paved narrow footpaths where only small farming vehicles could pass, paddies, crop fields, waste fields, grasslands, ponds, or farmer's one-storied houses were defined as the type of land use which was more unlikely to prevent female adults from flying to the focal trees than type 0 (type 1), because these were more unlikely to reduce flying spaces by female adults and to promote heavy traffic than type 0.

The number of larvae (N) of each species per host tree plus 1 was log-transformed. In each species, statistical significances of the regressions and correlations between the transformed values of larval density ($\log(N+1)$) and logarithms of (1) the total area of all forest types, (2) that of secondary deciduous broadleaf forest, (3) the distance from focal tree to the nearest stand of *Q. acutissima*, and (4) the number of host trees were tested. The difference in the transformed values of larval density ($\log(N+1)$) between the two types of land use (type 0 and 1) was tested by *t*-test.

Results

The average values of habitat components in the two study sites

The average values of habitat components measured in the two study sites and the statistical significance of the differences in the average values between the two sites are shown in Table 1. The total areas of all forest types and of secondary deciduous broadleaf forest surrounding the focal trees were significantly higher in SK than in IS site, although there were

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Table 2. Density of overwintering larvae of *Hestina japonica* and *Sasakia charonda*.

	Study site		
	Shimokomoriya	Isesaki	*P*
Hestina japonica larvae			
Number of trees investigated	42	54	
Number of trees where the larvae were found (%)[2]	37 (88%)	49 (91%)	>0.05[1]
Minimum–maximum number of larvae per tree	0–30	0–39	
Mean±SD of the number of larvae per tree	7.5±8.2	9.7±9.1	>0.05[3]
Sasakia charonda larvae (Kobayashi *et al.*, 2004)			
Number of trees investigated	42	54	
Number of trees where the larvae were found (%)[2]	38 (90%)	39 (72%)	<0.05[1]
Minimum–maximum number of larvae per tree	0–265	0–65	
Mean±SD of the number of larvae per tree	25.4±44.4	12.1±16.8	<0.05[3]
Two way ANOVA	df	*F*	*P*
Species	1	0.24	0.63
Study site	1	7.31	<0.01
Interaction (species × study site)	1	12.54	<0.01

[1] The difference in the proportion of numbers of trees where larvae were found to total number of trees investigated between the two sites was tested by a Chi-square test.
[2] Proportion to total number of trees investigated.
[3] The difference in the densities of larvae between the two sites was tested by Mann-Whitney *U*-test.

no significant differences in DBH and in the distances to the nearest *Q. acutissima* stand between the two sites. The number of host trees surrounding focal trees was significantly higher in IS than in SK site. The percentage of the number of host trees adjacent to the type of land use which are likely to prevent female adults from flying to the focal host trees (type 0) to the number of all focal trees was significantly higher in IS than in SK site.

Density of *H. japonica* and *S. charonda* larvae per host tree in the two study sites

The percentage value of the number of host trees, in which the larvae were found, to the total number of host trees investigated and the minimum, maximum and average larval densities per host tree of each species in the two sites are shown in Table 2. The differences in the percentage value and the density of *H. japonica* larvae between the two sites were not significant. The percentage value and the larval density of *S. charonda* were significantly higher in SK site than in IS site. Based on the result of two way ANOVA, in which study site and butterfly species were set up as two independent variables, the differences in the densities between the two study sites and among the interactions by study site and species were significant.

Relationship between larval density per host tree and habitat characteristics near host trees

In both sites, there were significant positive correlations between the density of *H. japonica* larvae and DBH of focal trees (Fig. 2), but there were no significant correlations between the larval density and the total area of all forest types, the total area of secondary deciduous broadleaf forests, the distance to the nearest *Q. acutissima* stand, and the number of host trees around a focal tree (Table 3). The differences in the density of *H. japonica* larvae between the two types of land use adjacent to the focal trees were not significant in either site (Fig. 2, *t*-test, SK site: t=0.46, P=0.65, IS site: t=−1.11, P=0.27).

In both sites, there was no significant correlation between the density of *S. charonda* larvae and the distance to the nearest *Q. acutissima* stand (Table 3), but there were significant cor-

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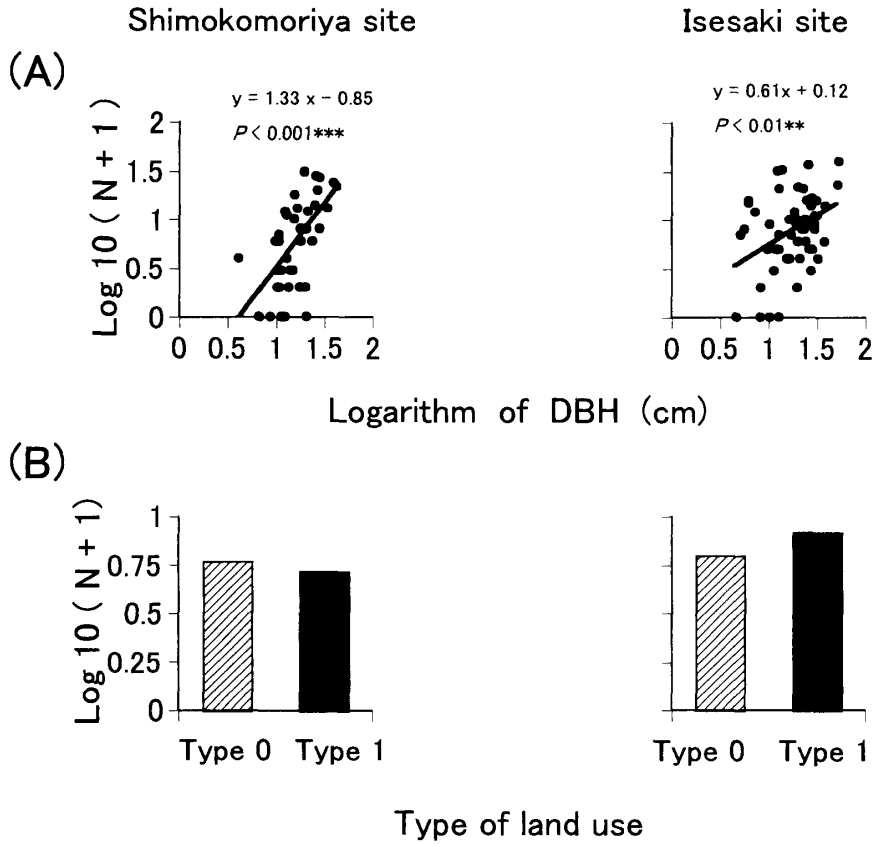

Fig. 2. Relationships between the number of *Hestina japonica* larvae per tree (*N*) and habitat characteristics. (A) DBH (cm) of focal host trees, (B) Type of land use adjacent to the forest edge containing the focal host trees. Type 0: ferroconcrete two- or more- story buildings, gravel parking area, or asphalt roads, which are likely to prevent female adults from flying to the focal host trees. Type 1: non-paved narrow footpaths where only small farming vehicles alone can pass, paddies, crop fields, waste fields, grasslands, ponds, or farmer's one-storied houses, which are more unlikely to prevent female adults of from flying to the focal trees than type 0. Simple linear regressions between the transformed number of larvae and transformed value of DBH were calculated and their significances were tested (A). The difference in the number of larvae between the two types of land use was tested by *t*-test (B).

relations between the larval density and the total area of all forest types, and the total area of secondary deciduous broadleaf forest (Fig.3). The differences in the larval density between the two types of land use adjacent to the focal trees were not significant in both sites (Fig. 3, *t*-test, SK site: $t=-1.42$, $P=0.16$, IS site: $t=-1.79$, $P=0.07$). In SK site, there was no significant correlation between the density of *S. charonda* larvae and the number of host trees around a focal tree, but there was a significant negative correlation between them in IS site (Fig.3). In IS site, there was no significant correlation between the density of *S. charonda* larvae and the DBH of a focal tree, but there was a significant positive correlation between them in SK site (Fig. 3).

Discussion

In this study, the results of two-way ANOVA suggested that *S. charonda* might be sensitive to decreases in secondary deciduous broadleaf forests as a result of urbanization, whereas *H. japonica* is superior to *S. charonda* in adaptability to reduction in the forest and might

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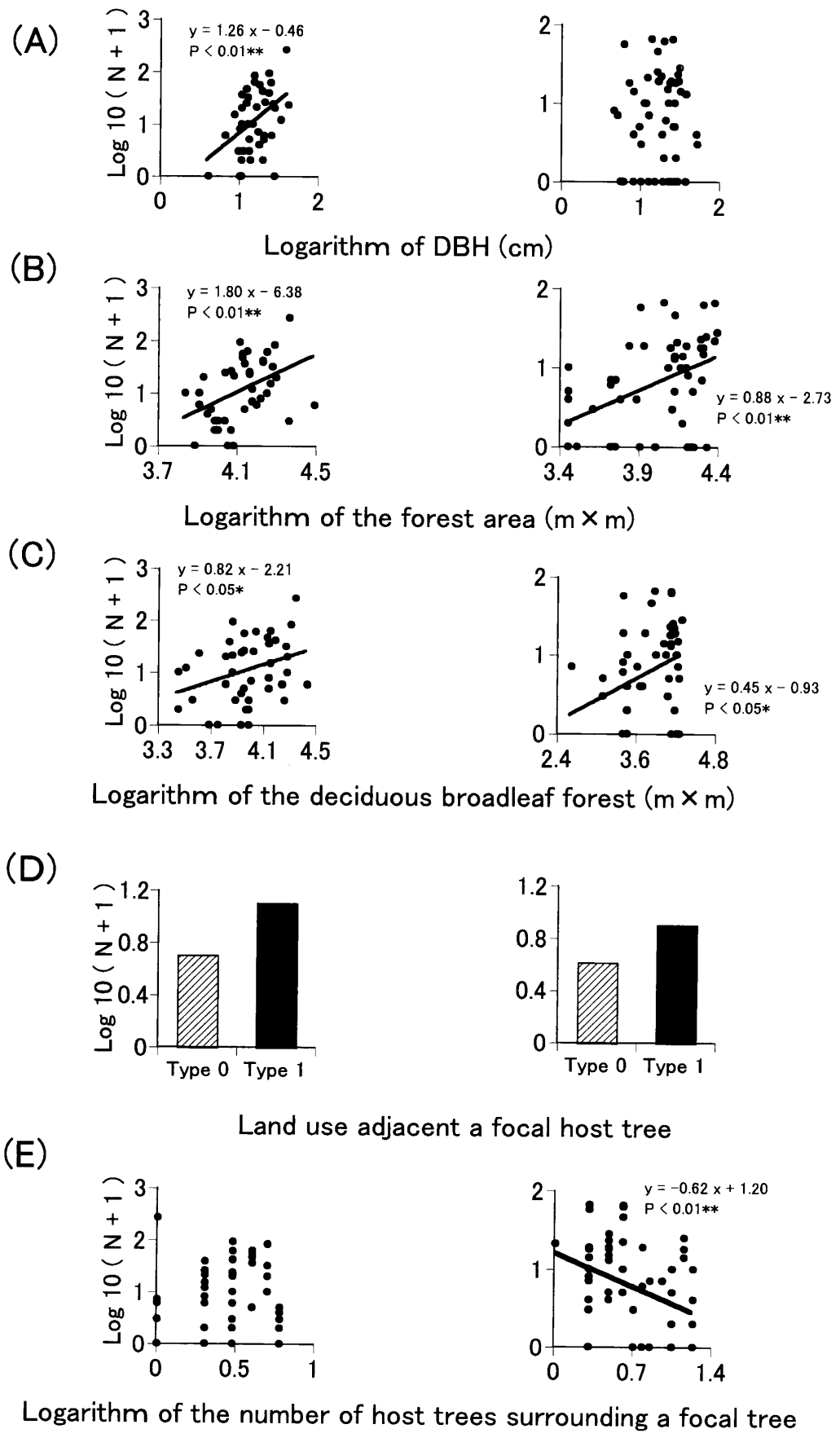
(A)
Log 10 (N + 1)
y = 1.26 x - 0.46
P < 0.01**
Logarithm of DBH (cm)
(B)
y = 1.80 x - 6.38
P < 0.01**
y = 0.88 x - 2.73
P < 0.01**
Logarithm of the forest area (m × m)
(C)
y = 0.82 x - 2.21
P < 0.05*
y = 0.45 x - 0.93
P < 0.05*
Logarithm of the deciduous broadleaf forest (m × m)
(D)
Type 0
Type 1
Land use adjacent a focal host tree
(E)
y = -0.62 x + 1.20
P < 0.01**
Logarithm of the number of host trees surrounding a focal tree

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Table 3. Statistical significances of the regressions and correlations between the logarithms of larval density per host tree and logarithms of various habitat components in two butterfly species, *Hestina japonica* and *Sasakia charonda*.

Independent variables		r_p[1]	Significance of r_p[2]	Regression line	Significance of the regression[2]
DBH					
H. japonica	Shimokomoriya	0.61	**	$y=1.33x-0.85$	**
	Isesaki	0.38	*	$y=0.61x+0.12$	**
S. charonda	Shimokomoriya	0.42	*	$y=1.26x-0.46$	**
	Isesaki	0.02	NS	$y=0.05x+0.71$	NS
Total area of all forest types surrounding the focal host tree					
H. japonica	Shimokomoriya	−0.02	NS	$y=-0.07x+1.02$	NS
	Isesaki	0.06	NS	$y=0.08x+0.56$	NS
S. charonda	Shimokomoriya	0.43	*	$y=1.80x-6.38$	**
	Isesaki	0.46	*	$y=0.88x-2.73$	**
Total area of secondary deciduous broadleaf forest surrounding the focal host tree					
H. japonica	Shimokomoriya	−0.11	NS	$y=-0.20x+1.51$	NS
	Isesaki	0.08	NS	$y=0.09x+0.53$	NS
S. charonda	Shimokomoriya	0.32	*	$y=0.82x-2.21$	*
	Isesaki	0.3	*	$y=0.45x-0.93$	*
Distances from a focal tree to the nearest stand of *Q. acutissima*					
H. japonica	Shimokomoriya	−0.29	NS	$y=-0.10x+0.91$	NS
	Isesaki	−0.08	NS	$y=-0.05x+0.96$	NS
S. charonda	Shimokomoriya	−0.21	NS	$y=-0.18x+1.37$	NS
	Isesaki	−0.08	NS	$y=-0.45x+0.90$	NS
Number of host trees surrounding the focal host tree (this number contains the focal host tree)					
H. japonica	Shimokomoriya	−0.03	NS	$y=-0.06x+0.75$	NS
	Isesaki	−0.18	NS	$y=-0.22x+1.22$	NS
S. charonda	Shimokomoriya	−0.01	NS	$y=-0.04x+1.05$	NS
	Isesaki	−0.36	**	$y=-0.62x+1.20$	**

[1] Pearson's correlation coefficient.
[2] *: $P<0.05$, **: $P<0.01$, NS: not significant ($P>0.05$).

have a different life history strategy from *S. charonda*.

In both sites, there were significant positive correlations between the density of *S. charonda* larvae and the total area of all forest types and the area of secondary deciduous broadleaf forest around the host trees, but there were no significant correlations between the density of *H. japonica* larvae and those habitat components as stated above. Why is the density of *S. charonda* affected by decrease of secondary deciduous broadleaf forests, whereas *H. japonica* is not? Possible explanations are as follows. Kobayashi and Inaizumi (2002) planted host trees of these butterflies in a meadow, a small narrow secondary deciduous broadleaf forest and a large secondary deciduous broadleaf forest. Then they counted the numbers of flying female adults of *S. charonda* and eggs laid by the females in each site.

Fig. 3. Relationship between the number of *Sasakia charonda* larvae per tree (N) and each environment factor. (A) DBH (cm) of focal host trees, (B) Forest area (m^2), (C) Secondary deciduous broadleaf forest area (m^2), (D) Type of land use adjacent to the forest edge containing the focal host trees. See Fig. 2 for the explanation of Type 0 and Type 1. (E) Number of host trees surrounding a host trees. Simple linear regressions between the transformed number of larvae and transformed value of DBH, forest area, secondary deciduous broadleaf forest area, and the number of host trees surrounding a host trees were calculated and their significances were tested (A, B, C, and E). The difference in the number of larvae between the two types of land use was tested by t-test (D).

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They found that the densities of the female adults and eggs laid in the meadow and in the small narrow secondary deciduous broadleaf forest were significantly lower than in the large secondary deciduous broadleaf forest (Kobayashi and Kitahara, in press). The mortality rates of inoculated young- and intermediate-instar larvae of *S. charonda* were reported to be higher in a meadow than in both a small, narrow broadleaf forest and a large broadleaf forest. Especially in the meadow, all of the inoculated larvae were completely destroyed (Kobayashi and Inaizumi, 2002). The high mortality rate in the meadow occurred from the first ten days of July to the middle ten days of August, and resulted from predation by a large number of killer ants, *Lasius sakagamii* or *Formica japonica*, climbing the host trees (Kobayashi and Inaizumi, 2002). The number of these ants climbing the host trees in the meadow was higher in the period stated above than in other seasons, and the period just corresponds to the season when the larvae of *S. charonda* hatch (Kobayashi, unpublished data). Therefore, in this study, the reasons why the density of overwintering larvae of *S. charonda* was affected by reductions in the secondary deciduous broadleaf forests may be (1) that the density of eggs laid by female adults decreased when the area of nearby secondary deciduous broadleaf forest decreased and/or (2) that the mortality rates of young- and intermediate- instar larvae increased when the area of the forest decreased. On the other hand, we observed that the female adults of *H. japonica* flew around and oviposited on host trees planted in the meadow, in the narrow, small broadleaf forest, and in the large broadleaf forest (Kobayashi, unpublished data). We also observed the larvae of this butterfly on the leaves of host trees in the same three sites. In particular, the larvae were observed in April and October in the meadow. However, in the meadow, this period corresponds to the season when the number of ants climbing on the host trees was low, compared with the summer season (from the first ten days of July to the middle ten days of August) (Kobayashi, unpublished data). Around the study area, it is speculated that *H. japonica* is multivoltine and the number of generations per year is 2 or 3 (Kobayashi, 2000*a*). If the larvae of *H. japonica* hatch on isolated host trees in the meadow during the period from the first ten days of July to the middle ten days of August, when the density of ants climbing the host trees is at its highest, the mortality rate of *H. japonica* larvae due to predation by ants may be as high as that of *S. charonda*. However, if the larvae of *H. japonica* hatch on the host trees after the last ten days of August, they will overwinter at the bases of the host trees, will climb host trees in early April, will pupate from the end of April to the first ten days of May, and then the adults will emerge in the middle of May. The development period of the larvae corresponds to the period when the density of killer ants climbing host trees in the meadow was low, except for the period from the first ten days of July to the middle ten days of August. Therefore, the survival rates of these larvae are probably higher than those of the larvae hatched in the periods from the first ten days of July to the middle ten days of August. One of the reasons why a significant correlation was not found between the density of overwintering *H. japonica* larvae and the area of secondary deciduous broadleaf forest around the host trees is that the female adults of *H. japonica* lay eggs on host trees quite independently of the area of the secondary deciduous broadleaf forest surrounding the host trees. Or another reason may be that the mortality rates and factors of *H. japonica* are different from those of *S. charonda* larvae, and are not affected by the area of the secondary deciduous broadleaf forest surrounding host trees. However, we need an experimental test for this hypothesis.

If the land use in the area adjacent to the secondary deciduous broadleaf forest edge including focal trees is 'type 0' such as ferroconcrete two- or more- story buildings, gravel parking area, asphalt roads, this land use type is likely to prevent female adults of both species from flying to the focal host trees. But the densities of overwintering larvae of both species were not affected by the types of land use adjacent to the focal trees. Although the reason

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was not clear, it was considered that at least in the present study area, the female adults of both species can find host trees and lay eggs on them even if there are ferroconcrete two- or more- story buildings, gravel parking area, or asphalt roads near the host trees. Also, larval mortality rates and factors of both species may not be affected by the type of land use in the areas adjacent to the secondary deciduous broadleaf forest edge including host trees.

In and around the study sites, a major adult food resource of *S. charonda* was the tree sap of *Q. acutissima* (Kobayashi and Inaizumi, 2003; Kobayashi *et al.*, 2004). Moreover, mark-recapture study (Kobayashi and Kitahara, in press) suggested that the feeding and flight activities of both sexes in mature *S. charonda* adults were limited to large broadleaf forests containing *Q. acutissima* stands with many sap-producing *Q. acutissima* trees and that long-distance dispersal of adult females searching for host trees seldom occurred. However, in this study, the larval density of *S. charonda* was not significantly correlated with the distance to the nearest *Q. acutissima* stand. As mentioned above, the densities of the female adults and eggs on host trees experimentally planted in a meadow and in a small, narrow secondary deciduous broadleaf forest were significantly lower than in a large secondary deciduous broadleaf forest (Kobayashi and Kitahara, in press). This large broadleaf forest contained plantations of *Q. acutissima* with many sap-producing *Q. acutissima* trees (Kobayashi and Kitahara, in press). The study also suggested that the feeding sites of adult *S. charonda* were located near the oviposition sites. In the present study, the reason why the density of *S. charonda* larvae was not significantly correlated with the distance to the nearest *Q. acutissima* stand may be (1) that some host trees are located near *Q. acutissima* stands with many sap-producing *Q. acutissima* trees and those locations are suitable for oviposition, but the areas of secondary deciduous broadleaf forest surrounding the host trees were narrow, resulting in high mortality rates of larvae and/or (2) that some host trees stand near the *Q. acutissima* stands, but there are no sap-producing trees in them. On the other hand, as well as *S. charonda*, one of the adult food resources of *H. japonica* was reported to be the tree sap of *Q. acutissima* (Fukuda *et al.*, 1983), but we did not observe that the density of adult *H. japonica* was higher at the *Q. acutissima* stands with many sap-producing trees than elsewhere (Kobayashi, unpublished data). *S. charonda* depended on *Q. acutissima* tree sap in large secondary deciduous broadleaf forests as their main resource. But adult *H. japonica* is unlikely to depend only on the tree sap of *Q. acutissima*.

In future, we need to solve the following questions: 1) are the mortality rates and factors of *H. japonica* larvae related to the area of the secondary deciduous broadleaf forest surrounding host trees? 2) what is the food resource of *H. japonica*? and 3) is the density of *H. japonica* larvae per host tree related to the distance from the host tree to the adult food resource? Solving these questions may clarify the reason why *S. charonda* and *H. japonica* coexist to some extent geographically, but have different local distribution patterns in Japan. Yet, the results of this study provided helpful clues for clarifying the reason stated above.

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References

Fukuda, H., Hama, E., Kuzuya, K., Takahashi, A., Takahashi, M., Tanaka, B., Tanaka, H., Wakabayashi, M., & Y. Watanabe, 1983. *The Butterflies of Japan* **2**: 269–276. Hoikusha, Osaka. (In Japanese).

Geographical Survey Institute, 1993. Aerial photographs.

NII-Electronic Library Service

The Lepidopterological Society of Japan

Inoue, T., 1990. Habitat selection of two fleabeetle species of the genus *Argopistes* (Coleoptera: Chrysomelidae) on their host trees. *Jap. J. appl. Ent. Zool.* **34**: 217–226 (in Japanese with English summary).

Japan Forest Technical Association, 1963. Area scale with dot grids S-II.

Kobayashi, T., 2000*a*. *Hestina japonica* C. & R. Felder. *In* Shin-Tochigiken-no-Chou-Henshu-Iinkai (Eds), [*Butterflies of Tochigi Prefecture* (rev. Edn)]: 224–225. Konchu-Aikoukai, Tochigi. (In Japanese).

————, 2000*b*. *Sasakia charonda* Hewitson. *Ibid*: 226–227. (In Japanese).

Kobayashi, T. & M. Inaizumi, 2002. Difference in mortality rates and factors of immatures before overwintering of the nymphalid butterfly, *Sasakia charonda* (Hewitson), in relation to vegetation shift surrounding the host plants. *Jap. J. Ent.* (N. S.) **5**: 35–49 (in Japanese with English summary).

————, 2003. The sex ratios of the wild adult populations in *Sasakia charonda* (Nymphalidae). *Trans. lepid. Soc. Japan* **54**: 156–162.

Kobayashi, T. & M. Kitahara, 2005. Effect of surrounding vegetation on the oviposition preference of *Sasakia charonda* (Lepidoptera: Nymphalidae). *J. Forest Res.* (in press).

Kobayashi, T., Tanimoto, T. & M. Kitahara, 2004. Relationship between rate of forest area and the densities of the nymphalid butterfly, *Sasakia charonda* Hewitson, and the host trees, *Celtis sinensis* Persoon. *Jap. J. Conserv. Ecol.* **9**: 1–12 (in Japanese with English summary).

Ministry of the Environment, 2000. http://www.biodic.go.jp/rdb/rdb_top.html

Morimoto, N., Fujino, M. & N. Tanahashi, 1991. Coexistence of the two closely related species of cabbage stink bug, *Eurydema rugosum* and *E. pulchrum* (Heteroptera: Pentatomidae), in the field in central Japan. I. Distribution, life cycle and host plant preferences of the two species. *Appl. Ent. Zool.* **26**: 435–442.

Ohsaki N., 1979. Comparative population studies of three *Pieris* butterflies, *P. rapae*, *P. melete* and *P. napi*, living in the same area. II. Utilization of patchy habitats by adults through migratory and non-migratory movements. *Researches Popul. Ecol. Kyoto Univ.* **20**: 273–296.

Price, P. W., 1984. *Insect Ecology* (2nd Edn). Wiley and Sons, New York.

摘　　要

栃木県真岡市におけるオオムラサキとゴマダラチョウの幼虫の分布と生息環境 (小林隆人・北原正彦)

ゴマダラチョウとオオムラサキは同じ寄主植物を利用し，寄主植物の根元で越冬するなど似たような生活環を持つチョウである．本研究では，これら2種について，越冬幼虫の密度と様々な環境要素との関係を，落葉広葉樹二次林 (以下，二次林) の断片化が進んでいる都市部と二次林が広く残存する都市郊外において調べた．オオムラサキの幼虫の密度は都市部よりも郊外において有意に高かったのに対し，ゴマダラチョウの幼虫の密度は郊外と都市部の間で有意な差がなかった．調査地と種を独立変数とした二元配置の分散分析の結果から，オオムラサキは都市化による二次林の減少に敏感であるのに対し，ゴマダラチョウはオオムラサキよりも二次林の減少への適応力が優れているなど，この2種は互いに異なる生活史戦略を持っていると思われた．寄主植物周囲の森林および二次林の面積とオオムラサキの幼虫の密度の間には都市と郊外の双方において正の相関が認められた．これに対し，ゴマダラチョウの幼虫の密度は木の周囲の森林や二次林の面積とは有意な相関がなかった．オオムラサキの幼虫の密度が周囲の二次林の面積の減少とともに低下したことには，二次林面積の減少によって雌成虫による産みつけられる卵の密度が低下したこと，もしくは若齢あるいは中齢幼虫の死亡率が高くなったことが関係していると思われる．一方，ゴマダラチョウの幼虫の密度と周囲の二次林面積との間に有意な相関が見られなかった理由の一つは，雌成虫が周囲の二次林面積に関係なく餌植物に産卵を行っていたことと思われる．この他に，幼虫の死亡要因がオオムラサキと異なっていて，死亡率が周囲の二次林面積に関連しないことも考えられる．本研究により，両種が日本において地理的にはある程度共存するものの，局所的には分布地域が異なる原因を明らかにするために有効な手掛かりが得られた．

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